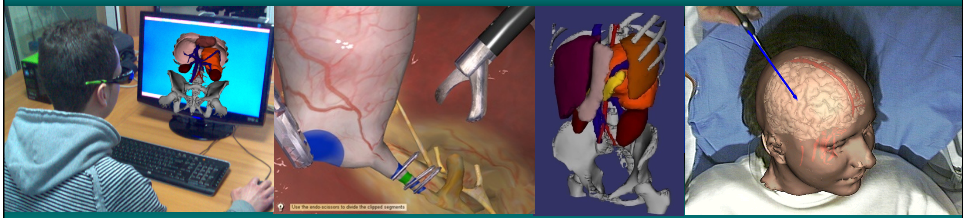
Department of Engineering for Innovation
University of Salento
Lecce, Italy



Tutorial:
New Applications of Virtual Reality and Augmented Reality in Medicine and Surgery

Lucio Tommaso De Paolis

Augmented and Virtual Reality Laboratory (AVR Lab)

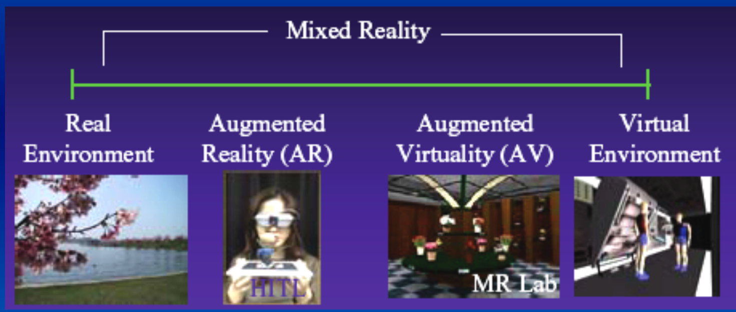
The Second International Conference on Global Health Challenges
GLOBAL HEALTH 2013
November 17 - 22, 2013 - Lisbon, Portugal

New Applications of Virtual and Augmented Reality in Medicine and Surgery

Overview

- Virtual Reality applications in medicine and surgery
- Augmented Reality applications in medicine and surgery
- visualization and interaction systems in medicine and surgery

Virtual and Augmented Reality



Virtual Reality Technology

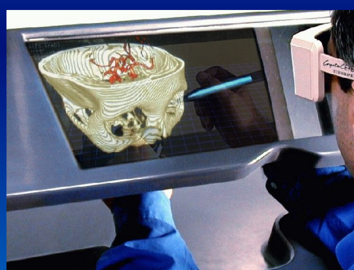
Virtual Reality Technologies

Virtual Reality is a collection of technologies that simulates a realistic environment and allows users to interact with it in real time and using their natural senses and skills

The aim of the Virtual Reality is to reproduce on the user a sensory experience as close as possible to the real one

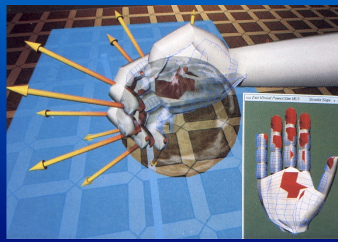
Interactions in the Virtual Environment

To interact in the virtual environment in a simple and intuitive way it is necessary to use specific interfaces able to allow the communication between the user and the world created in the computer



Interactions in the Virtual Environment

Force feedback, or haptic feedback, introduces the physical sensation into the virtual environment



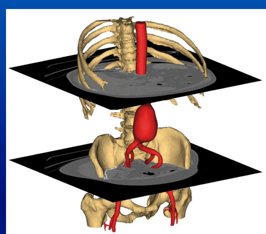
In order to provide on the user’s hand a force feedback it is necessity to use advanced human-machine interfaces (haptic interface) able:

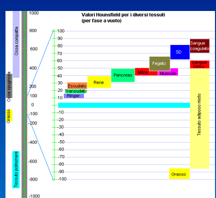
- to replicate the user’s movements in the virtual environment
- to reproduce the sensations associated with the interactions in the virtual environment

The user feels the forces generated in the virtual environment in response to the forces he applies

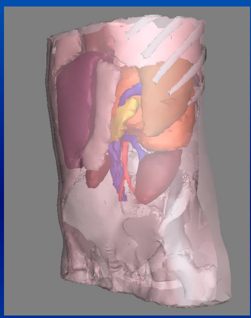
Building of the Virtual Environment

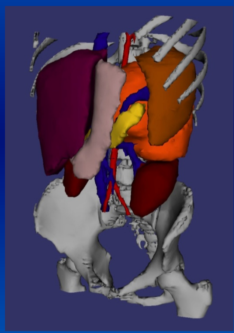
- the real patients’ images are processed in order to distinguish the anatomical structures and to associate different chromatic scales to the organs
- the segmentation and classification phases are carried out in order to obtain information about the size and the shape of the organs

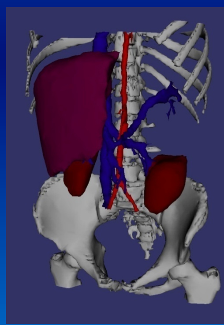




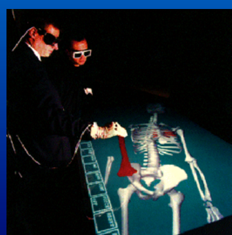
Building of the Virtual Environment



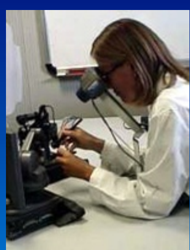




Virtual Reality in Medicine



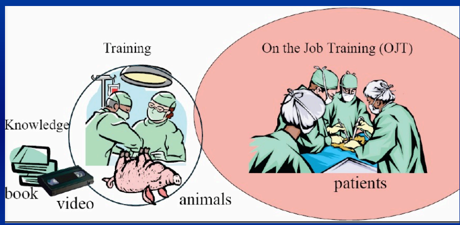
- Computer Aided Surgery
- Diagnosis
- Pre-operative Planning
- Training
- Telesurgery
- Rehabilitation



Current Practice in Surgical Training

The outcome of a surgical procedure is closely related to the skills of the surgeon

- animals: different anatomy
- cadavers: different physiology
- patients: risks to patient safety



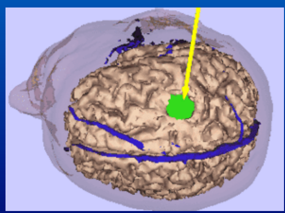
For the surgeons to reach and to remain at a high level of technical skills are required new and alternative ways of performing surgical training

Current teaching practices have difficulty meeting the challenges of modern medicine

Why simulation?

The training on virtual patients met the growing need for training in surgery

Many of these procedures need to be learned by repetition; new and unusual surgical procedures can be practiced in a safe manner



- to increase experience
- to increase patient safety
- to practice medical skills
- to plan the operative strategy

Simulations will be part of the new system of graduate medical education

Minimally Invasive Surgery

advantages:
- shorter hospitalizations
- faster bowel function return
- fewer wound-related complications
- a more rapid return to normal activities

limitations:
- the imagery is in 2D
- the surgeon can estimate the distance of anatomical structures only by moving the camera

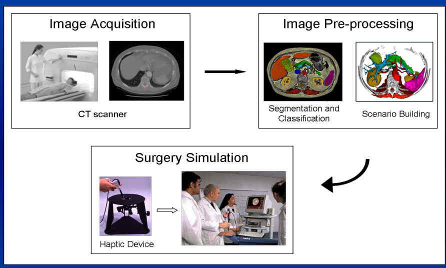
Simulators for Surgical Training

A surgery simulator requires the calculation of the real-time force feedback sensation and also the modelling of the organs behaviour, its deformations and cutting in tissue

Virtual Simulator

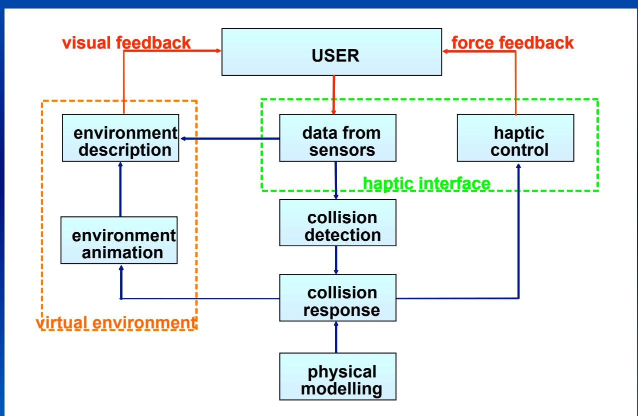
Virtual simulator = virtual environment + haptic interface

Technical Challenge	Description
Image segmentation	Translation of patient-specific imaging into virtual 3D models
Graphic rendering	Production of visual representation of virtual volume using surface mesh rendering and surface textures
Graphic display	Holographic or 3D devices for display of visual information
Physical modeling	Use of mass-spring, finite element, or other physical models to represent different tissue characteristics and dynamic changes
Collision detection	Computational detection and reaction to the intersection of two virtual volumes, such as an instrument and the brain
Haptic interaction	Articulating arms or tactile sensor for tactile interaction with virtual environment



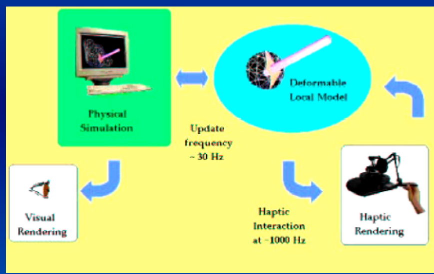
From several years simulation was validated by the scientific community and it was shown that VR simulators can speedup the learning process and improve the proficiency of surgeons

Surgical Simulator

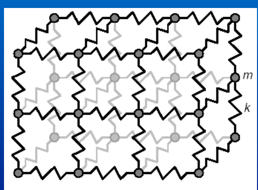


Surgical Simulator

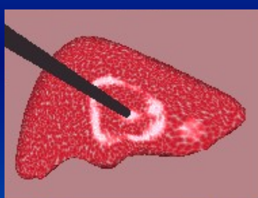
- collision detection
- collision response
- physical modelling



Physical Modelling

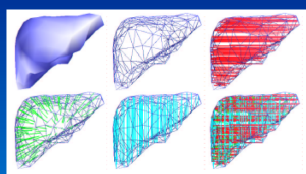


Mass-spring damping method



Finite Element Method (FEM) method

Long Element Model (LEM) method



Laparoscopy Training Simulator

VEST System One (VSOne)

The "Virtual Endoscopic Surgery Training" (VEST) system was developed within the framework of the partners Forschungszentrum Karlsruhe - Institut für Angewandte Informatik and the company Select IT VEST Systems AG – Bremen

Origin: Forschungszentrum Karlsruhe

Karlsruhe Virtual Endoscopic Surgery Trainer (VEST)

www-kismet.iai.fzk.de

Laparoscopy Training Simulator

LapSim® System

LapSim System utilizes advanced 3D technology, including interactive live video, to provide the student with a realistic virtual working environment

Practice sessions can vary in graphic complexity as well as in the level of difficulty

Surgical Science Ltd - Sweden

www.surgical-science.com

By courtesy of Surgical Science Ltd

Laparoscopy Training Simulator

Surgical Science Ltd - Sweden

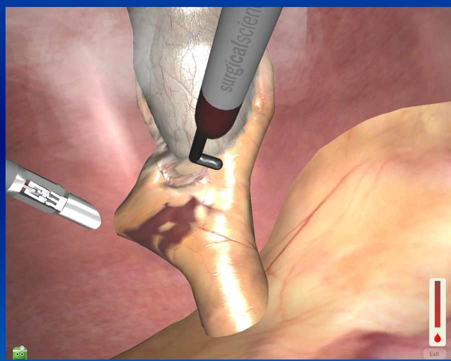
www.surgical-science.com

LapSim® System

The simulated tissue in LapSim Dissection reacts realistically to the user's manipulations

Dissection may be carried out using different instruments, each interacting with the simulated tissue in a realistic way

Once the bile ducts and blood vessels have been dissected free, clips are applied, and the vessels and ducts cut



By courtesy of Surgical Science Ltd

Laparoscopy Training Simulator

Procedicus MIST™

This system provides a graded series of training exercises designed to develop surgical technique employed in such procedures as laparoscopic cholecystectomy

The use of left and right hand training exercises encourage ambidexterity

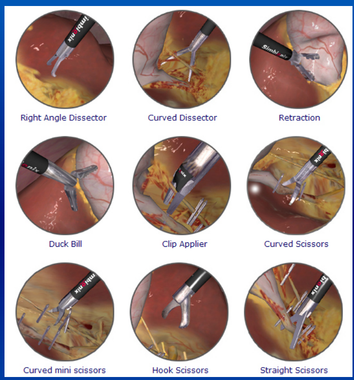
The system measures performance by time to task completion, number of errors, and overall exercise efficiency

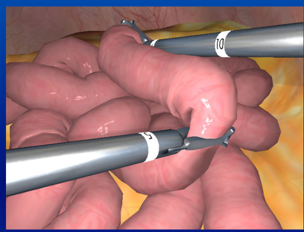
Mentice - Sweden

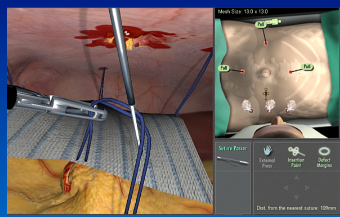
www.mentice.com

By courtesy of Mentice

Laparoscopy Training Simulator







LAP Mentor II

Simbionix USA Corp.

www.simbionix.com

NeuroTouch: A Virtual Simulator for Cranial Microneurosurgery Training

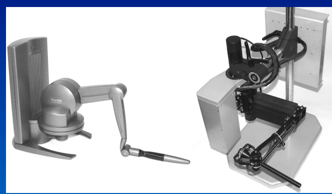
NeuroTouch is a virtual simulator with haptic feedback designed for the acquisition and assessment of technical skills involved in craniotomy-based procedures

Prototypes have been set up in 7 teaching hospitals across Canada for beta testing and validation and to evaluate integration of NeuroTouch into a neurosurgery training curriculum

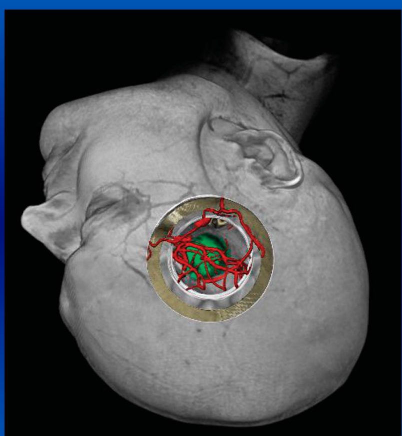
NeuroTouch: A Virtual Simulator for Cranial Microneurosurgery Training

Its main components are a stereovision system, bimanual haptic tool manipulators, and a high-end computer

Training tasks were built from magnetic resonance imaging scans of patients with brain tumors



NeuroTouch: A Virtual Simulator for Cranial Microneurosurgery Training



Virtual surgical corridor view showing segmented tumor (green), blood vessels (red), and cranium (beige)

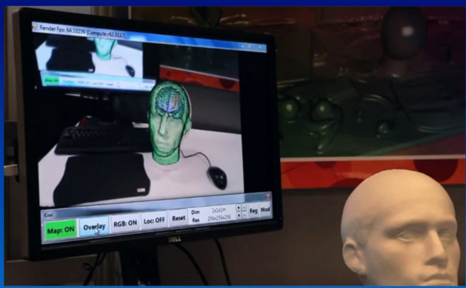
NeuroTouch allows simulating brain tumor removal using a craniotomy approach on 3 training tasks using the surgical aspirator, the ultrasonic aspirator, bipolar electrocautery, and microscissors

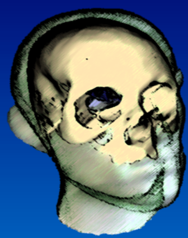
The surgical models are realistic enough, since their appearances are based on MR scanner data and the mechanical properties are derived from experimental in-vitro measurements

Kinect + Brain Scan = Augmented Reality

The Microsoft Research Cambridge team has recently put together a Kinect and a touch screen tablet in order to provide neurosurgeons with interactive 3D visual information

At the 13th annual Microsoft TechFest, Ben Glocker showed a prototype system that would allow neurosurgeons to prepare for surgery by looking inside a patient's brain





HERMES Project

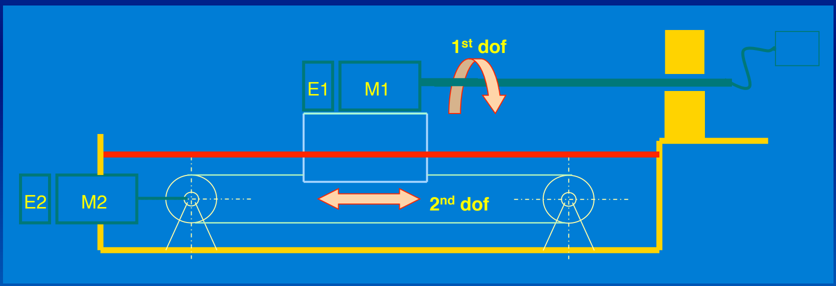
The aim of the project is to build a system to simulate the Coronary Stent Implant, a cardiac procedure that involves placing a stent in a narrowed artery

- the insertion of a guide-wire and a stent catheter
- the balloon catheter with stent is placed in the centre of the blockage
- the balloon is inflated to expand the stent
- the balloon is removed and the stent is implanted in the artery

HERMES Haptic Interface

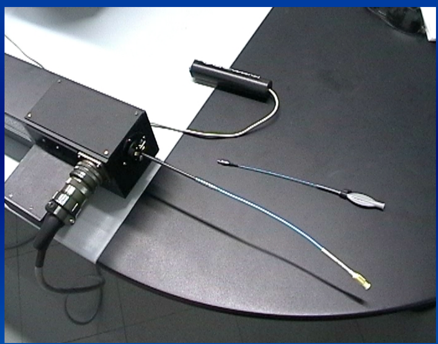
1^{st} degree of freedom: rotation movement

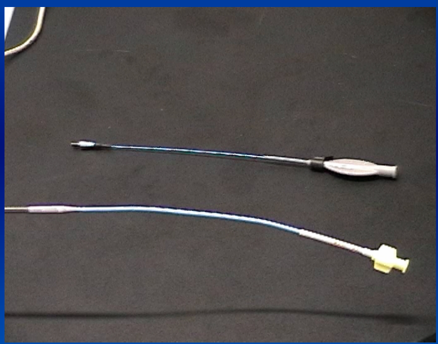
2^{nd} degree of freedom: translation movement



(PERCRO Laboratory, Scuola Superiore S. Anna – Pisa)

HERMES Haptic Interface



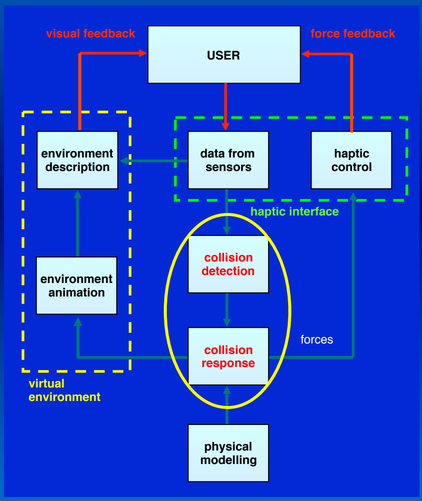


(PERCRO Laboratory, Scuola Superiore S. Anna – Pisa)

Interactions in the Virtual Environment

Interactions between artery and medical instrument are performed by:

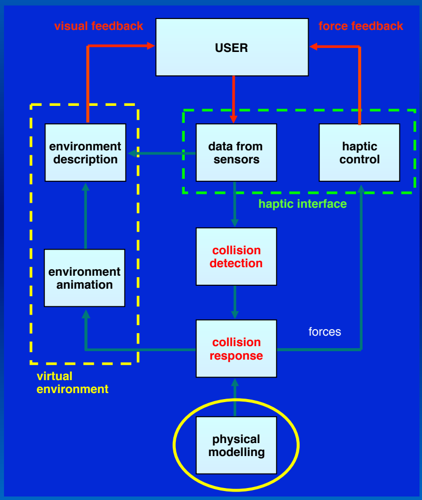
- collision detection module to detect the contact points
- collision response module to generate the contact forces produced in the virtual environment



The Physical Modelling

Finite Element Model (FEM) is computationally intensive and interactive rates of deformation can be obtained in a two-step process:

- a pre-processing stage is used to compute a set of elementary deformations of the model
- a real-time stage where the deformations are computed as a linear combination of the pre-computed deformations



The Physical Modelling

The pre-processing stage can take between a few minutes and several hours depending on the model size and the desired accuracy level

The result of the pre-processing stage can be saved for further simulations and therefore needs to be performed only once for a given model

The Physical Modelling

In the pre-processing stage we have:

- to calculate the displacement of each free node in the mesh

$[T^u_{nk}]$

- to calculate the components of the elementary force at node k

$[T^f_k]$

- to store in a file the tensors associated to the model

In the real-time stage we have to calculate:

- the displacement u_n of a node

$$u_n = [T^u_{nk}]\frac{u^*_k}{\|u^*_k\|}$$

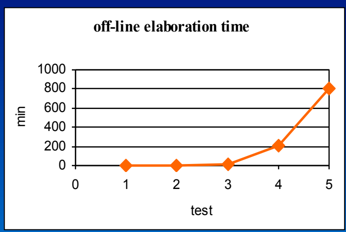
- the force associated to a node k

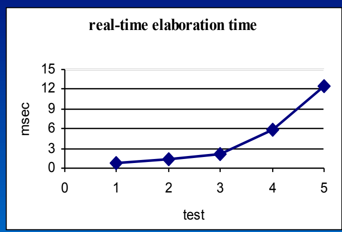
$$f = [T^f_{nk}][u^*]$$

The Physical Modelling

Increasing the desired accuracy level, some tests have been performed in order to calculate times of the off-line and the real-time elaborations

	test 4	test 5
number of tetrahedrons	989	2506
number of nodes on surface	131	249
off-line elaboration time (h)	3	13
real-time elaboration time (ms)	5,88	12,39



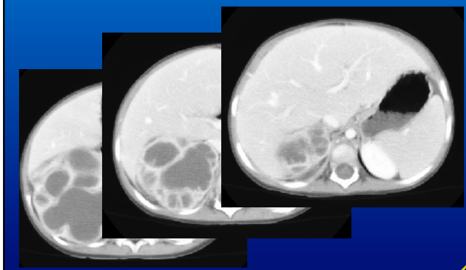


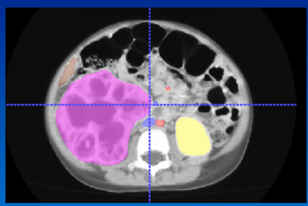
ARPED Project

ARPED - Augmented Reality Application in Pediatric Minimally Invasive Surgery

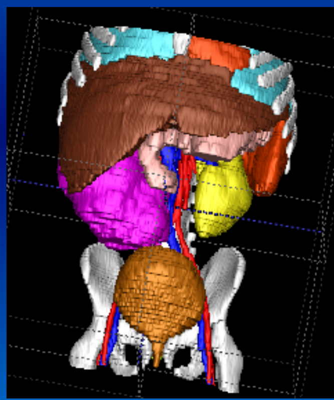
- building the 3D model from the patient’s medical images
- to identify the points of the trocar insertion
- simulate the use of laparoscopic instrumentation
- measuring distances
- AR to augment the real scene

ARPED Project

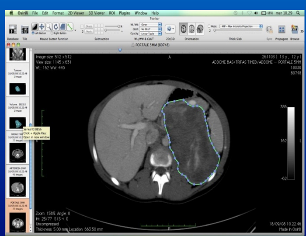


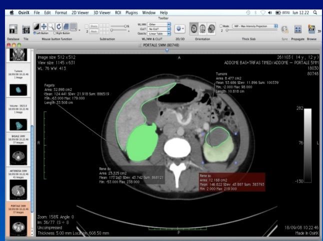


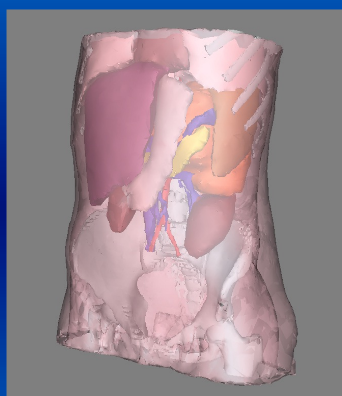
1° case:
child with the Wilms tumor



ARPED Project







2° case:
child with a tumor of the peripheral nervous system (ganglioneuroma)

Informed Consent

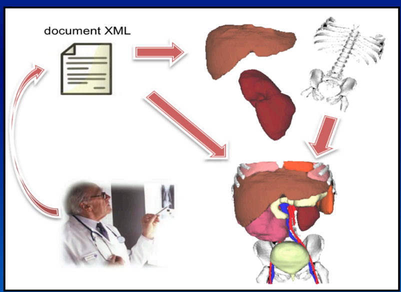
In the current climate of increasing awareness, patients are demanding more knowledge of the operative process

The term "informed consent" explains the process by which, before treatment, comprehensive and impartial information regarding a planned operative procedure is provided to a patient so that he can understand the implications of the procedure before consenting

Informed consent is a process of communication between patient and physician that results in the patient's authorization or agreement to undergo a specific medical intervention

ARPED Project

All the patient’s information (personal details, diseases, specific pathologies, diagnosis, medical images, 3D models of the organs, notes of the surgeon, etc.) are structured in an XML file associated to each patient



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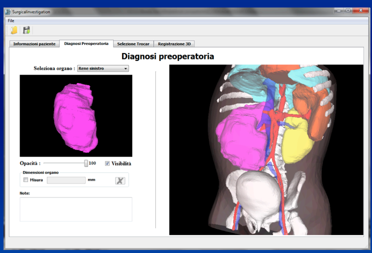
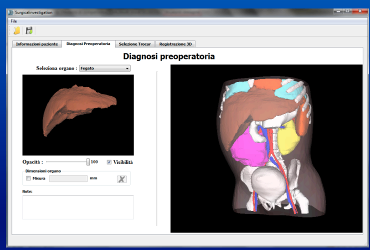
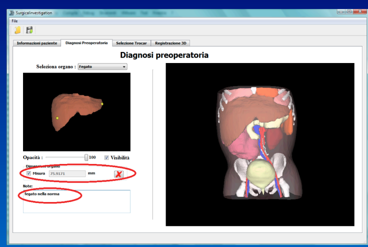
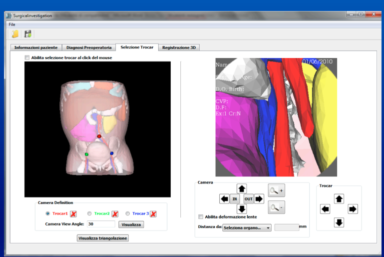
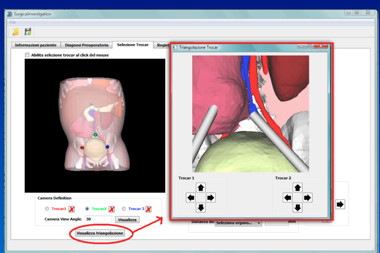


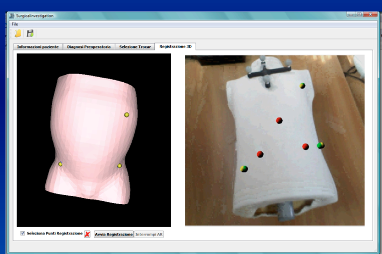




ARPED Project



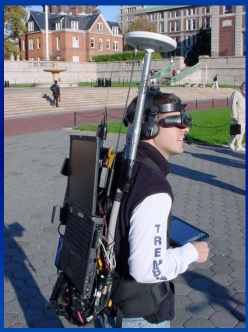




Augmented Reality Technology

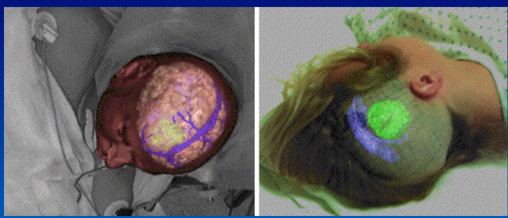
Augmented Reality Technology

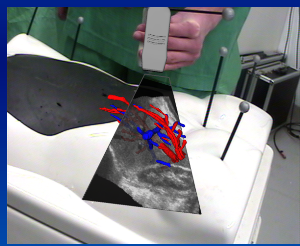
- optical see-through
- video see-through
- retinal display
- handheld display



Augmented Reality in Surgery

- Augmented Reality blends virtual and real in the real environment
- the basic idea is to provide a “X-ray vision“
- to use the high accuracy of medical images not only for diagnostics, but for the operation itself overlaying an image to the surgical field



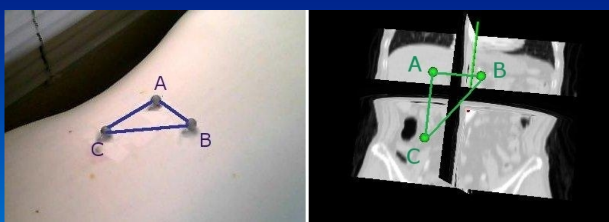


Augmented Reality in Surgery

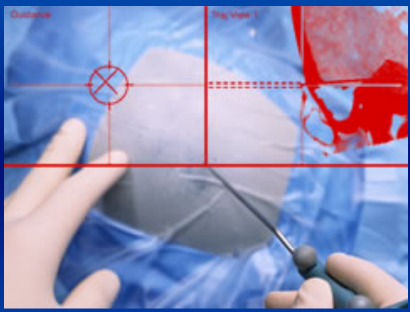
In order to have a perfect correspondence between virtual and real organs it is necessary to carry out an accurate registration phase that provides as result the overlapping of the virtual 3D model of the organs on the real patient

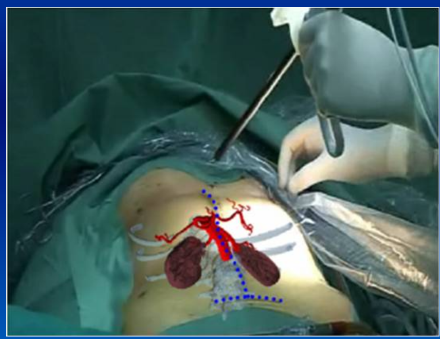
The registration phase is carried out just once at the beginning of the surgical procedure

the registration algorithm is based fiducial points

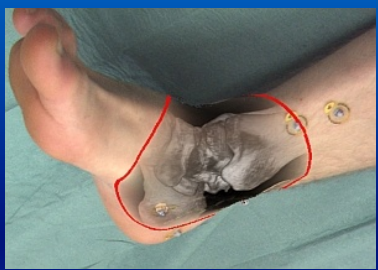


Augmented Reality in Surgery





Augmented Reality in Surgery



AR applications in Orthopedy

Augmented Reality in Surgery

IRCAD

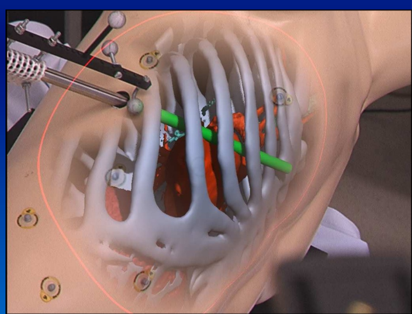
(Istitut de Recherche Contre le Cancers de l'Appareil Digestif) Stransburg - France

ODYSSEUS Project:
3D patient modelling, cooperative surgical planning and simulation in robotized surgery

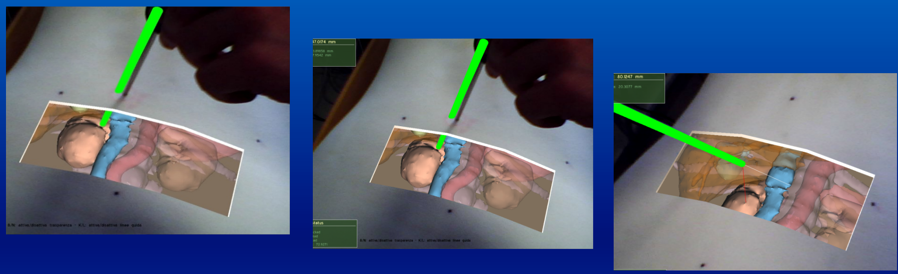
Augmented Reality in Surgery

CAMP

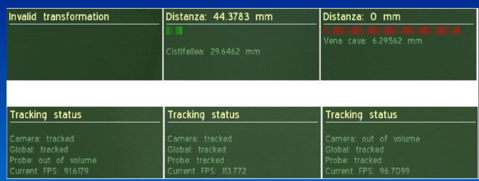
(Computer Aided Medical Procedures) Munchen - Germany



Augmented Reality in Surgery



information on the distance



RFA Ablation of the Liver Tumours

Hepatic Cancer

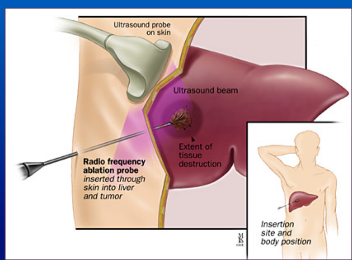
Hepatic cancer is one of the most common solid cancers in the world
The use of chemotherapy rarely led to good results in long-term survival rate; the chemotherapy produces negative effects in the patient's lifestyle

Today surgery is the best approach to avoid the death of the patient and the reversion of hepatic cancer (only from 5 to 15 per cent)

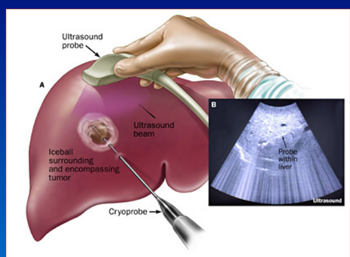
Patients with confined disease of the liver could not be candidates to resection because of multifocal disease (proximity of tumor to key vascular or biliary structures)

Hepatic Cancer

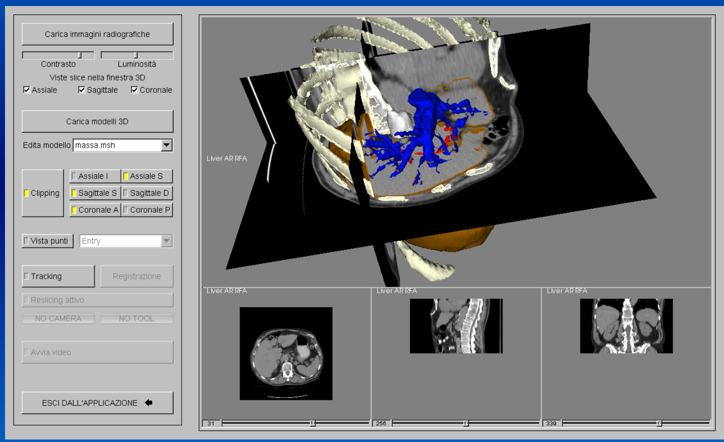
The Liver Radiofrequency Ablation (RFA) consists in the placement of a needle inside the liver parenchyma to reach the centre of the tumour



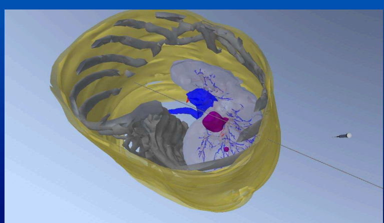
When the lesion is reached, an array of electrodes is extracted from the tip of the needle and a RF current is injected in the tumour tissue in order to cause the tumour cell necrosis for hyperthermia

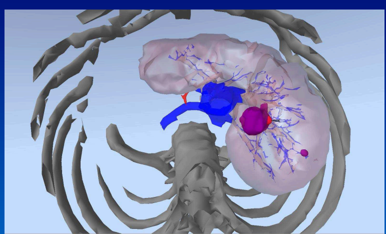


AR in RFA Ablation of the Liver Tumour



Training in Liver Tumour Ablation





Human-Computer Interaction

Visualization and Interaction

New interfaces able to interpret in real-time the user's gestures for the navigation and manipulation of 3D models

The systems can be used in medicine for diagnosis and pre-operative planning

- visualization and navigation system
- virtual touch-screen
- Stereoscopic vision
- interaction with Kinect

Technologies Used - NDI Polaris Vicra

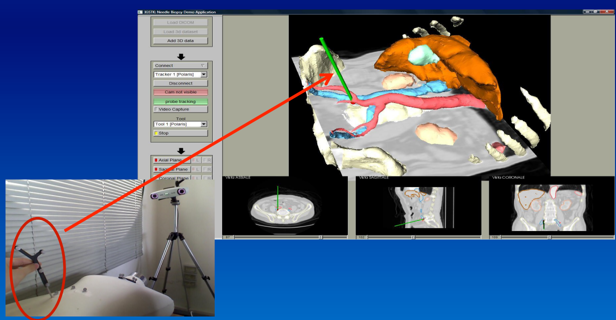
The NDI Polaris Vicra is an optical tracker already in use in the operating rooms during surgical procedures

It provides precise, real-time spatial measurements of the location and orientation of objects or tools within a defined coordinate system

Visualization and Navigation System

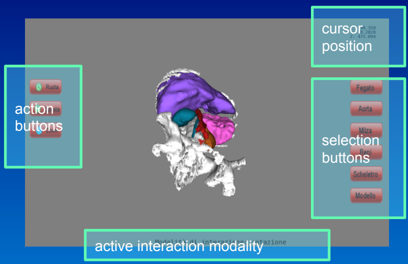
An advanced visualization and navigation system has been developed as support for a more accurate diagnosis and in the surgical preoperative planning

The surgeon has the possibility to visualize both the traditional patient information, as the TC image set, and a 3D model of the patient's anatomy built from this



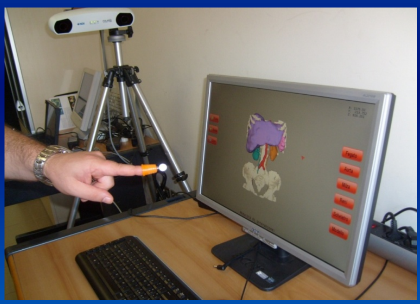
Virtual Interface

- first prototype designed to avoid contact with the computer
- interactions in real-time
- the virtual interface appears as a touch-screen suspended in free space
- the interaction happens by pressing the buttons located in the interface



Virtual Interface

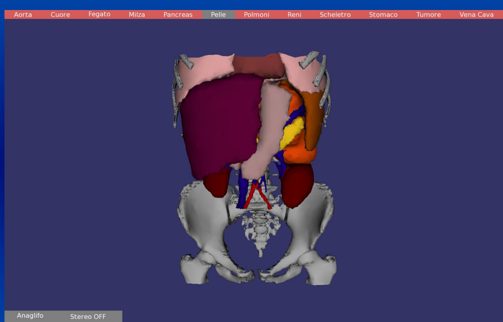
Finger movements are detected by means of the optical tracker and are used to simulate touch with the interface

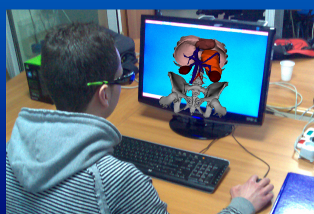


Stereoscopic Vision

- small LCD panels that could be transparent or opaque
- the control signal is generated by the circuitry contained in the glasses and is synchronized to the synchronization signal transmitted to the glasses via cable or infrared connection

Stereoscopic Vision





Gestural Interface

Bacterial Contamination of Computer Keyboards in a Teaching Hospital

Maureen Schultz, MSN, CIC; Janet Gill, BSN, CIC; Sabiha Zubairi, MT; Ruth Huber, MS, CIC; Fred Gordin, MD

ABSTRACT
We tested 100 keyboards in 29 clinical areas for bacterial contamination. Ninety five were positive for microorganisms. (including one *Streptococcus*, *Clostridium perfringens*, *Enterococcus* (including vancomycin-resistant *Enterococcus*), *Staphylococcus aureus*, fungi,

COMPUTER KEYBOARD AND MOUSE AS A RESERVOIR OF PATHOGENS IN AN INTENSIVE CARE UNIT

Bernd Hartmann, Dr med.,[1] Matthias Benson, Dr med.,[1] Axel Junger, Dr med. habil,[1] Lorenzo Quinzio,[1] Rainer Röhrig, Dr med.,[1] Bernhard Fengler,[1] Udo W. Färber, Dr rer. nat.,[2] Burkhard Wille, Prof Dr med.,[2] and Gunter Hempelmann, Prof Dr med. Dr h.c.

Hartmann B, Benson M, Junger A, Quinzio L, Röhrig R, Fengler B, Färber UW, Wille B, Hempelmann G. Computer keyboard and mouse as a reservoir of pathogens in an intensive care unit.
J Clin Monit 2004; 18: 7–12

ABSTRACT. Objective. User interfaces of patient data management systems (PDMS) in intensive care units (ICU), like computer keyboard and mouse, may serve as reservoirs for the transmission of microorganisms. Pathogens may be transferred via the hands of personnel to the patient causing nosocomial infections. The purpose of this study was to

Gestural Interface

Touchless Gestural Interaction

The Kinect is a depth sensor created by the Israeli PrimeSense company and is based on the technology of structured infrared light

The aim is to obtain 3D information on the observed scene

depth image

tracking

Touchless Gestural Interaction

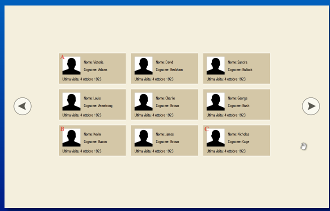
The interaction is based on the movements of only one hand

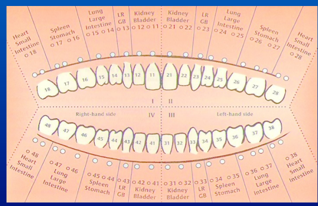
The user can decide when to start and end a session of interaction

Outside of a session of interaction, the interface ignores all user's gestures

The main modality of gestural interaction reminds the common use of the mouse

Touchless Gestural Interaction



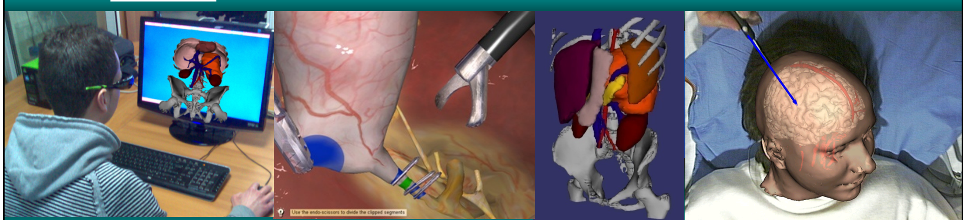


The developed system has been designed according to dentists needs

The system lets you:

- browse a list of patients
- pick up one of these
- refer to his data
- display diagnostic images
- Interact with the image in order to highlight some specific details

Department of Engineering for Innovation
University of Salento
Lecce, Italy



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